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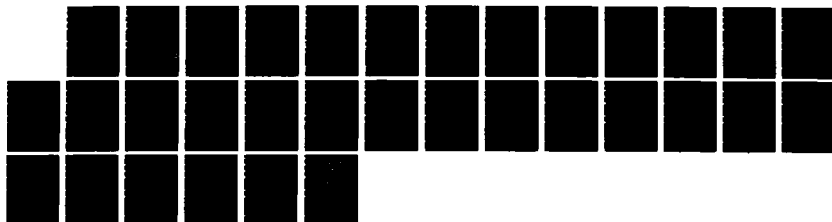
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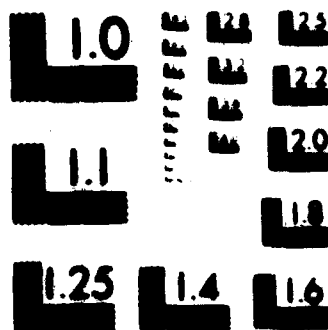
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STABILITY FOLLOWING COMBINED MAXILLARY AND MANDIBULAR
OSTEOTOMIES TREATED WITH RIGID INTERNAL FIXATION

BY

John H. Law, D. D. S.

A thesis presented to the Research Committee of the
Department of Orthodontics, Washington University School
of Dental Medicine in partial fulfillment of the
requirements for the degree of Master of Science

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Approved

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Abstract

Skeletal stability was examined in sixteen patients following combined maxillary and mandibular osteotomies using rigid internal fixation. The postoperative changes (T2 to T3) of all measured anatomic landmarks were generally less than 1.0mm for linear measurements, and less than 2.0 degrees for angular measurements. The removal of intermaxillary fixation (IMF) splints accounted for 85% to 95% of the counterclockwise rotation in the proximal and distal segments from T2 to T3. Maxillary inferior repositioning and large mandibular advancements exhibited the greatest tendency for relapse; however, the changes were less than comparable procedures using non-rigid methods for stabilization. For a given category of surgical procedures, relapse was essentially unrelated to the magnitude of the surgical repositioning. Although the use of suspension wires, IMF, and transosseous wire fixation have traditionally provided satisfactory clinical results, the use of rigid internal fixation in combined double-jaw procedures provides better stabilization of dentosseous segments when compared to non-rigid fixation, and is particularly indicated in complex surgical procedures.



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DEDICATION

To my wife, Dinah, my daughter, Juliana Christie, and my son, Jonathan David, who were instrumental in the realization of this effort. Their prayers, patience, and love was a continual encouragement.

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INTRODUCTION

Combined double-jaw surgical procedures of the maxilla and mandible using traditional transosseous wire fixation (with or without interpositional bone grafts), and 6 - 8 weeks of intermaxillary fixation, have shown significant postoperative relapse.¹⁻³ A retrospective study by LeBanc, Turvey, and Epker¹ of 100 consecutive patients treated with double-jaw procedures, described three contributory events causing relapse using non-rigid transosseous wire fixation: (A) Immediate relapse Type I, which occurs when the postsurgical posterior maxillary bony interphases lack support or are nonexistent, despite properly positioned condyles and adequate skeletal fixation; (B) Immediate relapse Type II, occurs when the condyles are not seated in the fossa, inadequate skeletal fixation, and/or compromised posterior maxillary bony interphases result in very early relapse during fixation; and (c) Delayed relapse, in which cases exhibit good short-term stability, but show slow measurable long-term relapse (6 to 24 months) secondary to progressive condylar resorption or condylar remodeling.

In recent years, methods to control and stabilize osteotomy segments by rigid fixation using bone screws for compression osteosynthesis in mandibular osteotomies, and bone plates or Steinmann pins in maxillary procedures have been developed.⁴⁻¹⁵ Proponents of rigid fixation techniques report more stable surgical results, enhanced bone healing, early to immediate restoration of function by shortening or eliminating intermaxillary fixation, and simultaneously curtailing postoperative complications involving airway management.^{5-7,10-18} Van Sickels and Flanary¹³ have stated that when rigid fixation is employed, it is possible to check passive condylar function prior to incision closure; thereby, improving control over a major cause of relapse.¹⁹⁻²⁸ Reitzik and Schoor²⁹ using non-human primates to compare rigid and semirigid fixation across a fracture site in the mandible, found healing to occur by primary intention without formation of a visible external callus; whereas, the semirigid sites resulted in fibrous tissue (periosteal) callus formation and healing by secondary intention. Six weeks following surgery, the rigid sites were found to be twice the strength of the semirigid sites with 50% less cross-sectional area. Reitzik³⁰ noted that interfragmentary gaps of 0.8mm or less across fixation sites resulted

in primary bone healing. Bone gaps healing by secondary intention greater than 0.8mm resulted in a fibrous union. Studies have also reported improved patient acceptance using rigid fixation techniques in combined two-jaw surgical procedures through improved oral hygiene, nutritional maintenance, early mandibular mobilization and masticatory function, improved speech, and resumption of orthodontic treatment in shorter periods of time. 6,10,12,13

Most of the quantitative data evaluating the stability of rigid osseous fixation has been reported on mandibular osteotomy procedures; however, few stability studies on maxillary osteotomies have been completed which have included two-jaw procedures in their samples.^{5,7-9} Reports by Brammer et al.,³¹ Moser and Freihofer,³² and Carlotti and Schendel³³ have stated greater stability in bimaxillary surgery than single jaw procedures. Stability in bimaxillary surgery has been reported as better than single jaw surgery due to physiologic muscle splinting of the jaws.^{33,34} However, current concepts of stability and relapse using rigid fixation in bimaxillary procedures have been either empirically derived or extrapolated from studies on single jaw procedures.^{5,7-9}

Although the biologic basis of skeletal relapse is controversial, several etiologic factors have been cited as contributing to relapse using rigid and/or non-rigid transosseous fixation during and following intermaxillary fixation (IMF). Contributory factors include insufficient intraoperative bone reapproximation and graft placement,^{1,4,5} stretching the pterygomasseteric sling and connective tissues,^{19-25,28} inadequate elimination of dental compensations during pre-surgical orthodontics,³³⁻³⁵ non-passive positioning of fixation plates in maxillary procedures resulting in torsional stresses,⁷ mechanical interferences of the nasal septum,⁹ influences of paramandibular musculature and tissues,^{13,19,28} and condylar displacement during placement of fixation plates and/or screws.^{1,10,12,14,22-24,27}

The use of rigid internal fixation has been reported to favorably control type I or II skeletal relapse, described by LeBanc et al.,¹ by providing rigid posterior maxillary support in LeFort I osteotomies with interpositional grafts, and limit the effects of proximal segment rotation with rigid stabilization, passive condylar seating, and maintaining the physiologic boundaries of the pterygomasseteric sling and paramandibular tissues^{4,10,16,34} Although passive condylar seating of the proximal segment has been

suggested as a means to control delayed relapse resulting in progressive condylar remodeling, the etiologic factors have not been clearly elucidated. The use of rigid internal fixation has not been shown to control this type of relapse.¹⁵

The purpose of this study was to descriptively evaluate the skeletal stability following simultaneous maxillary and mandibular osteotomies using rigid internal fixation. The parameters used in this study measured the changes of anatomic landmarks in magnitude and direction. They were as follows: (1) the displacements of A point (measuring upper anterior facial height) and B point (measuring total anterior facial height) relative to their pre-surgical positions along fixed horizontal and vertical reference planes; (2) posterior facial height; (3) effective mandibular length; and (4) changes in angular measures for proximal segment rotation, interfragment interaction between the proximal and distal segments, and distal segment rotation. The cephalograms of sixteen patients were analyzed to determine: (1) the surgical changes produced; (2) relapse associated with the repositioned osteotomy segments in long-term follow-up; and (3) the net long-term surgical result.

MATERIALS AND METHODS

Patient Data

Radiographic data were obtained on patients treated in the private practice of the surgeon (K.S.R.) between 1984 and 1987. The sample included the records of 16 patients (4 males and 12 females) who were treated surgically for the correction of clinically and cephalometrically diagnosed bimaxillary dentofacial dysplasias. The ages of the patients ranged from 11 to 43 years, with a mean of 29 years.

The criteria for patient selection were all patients treated by the surgeon (K.S.R.) with diagnosed maxillary and mandibular dentofacial dysplasias, requiring simultaneous orthognathic correction with rigid internal fixation. Concomittant surgical and orthodontic care was coordinated and planned for each patient by the surgeon (K.S.R.) and the referring orthodontist in private practice. Presurgical orthodontic preparation was implemented in all cases to decompensate dental relationships allowing for optimal skeletal correction.

Surgical Method

The sequence for the simultaneous mobilization of the maxilla and mandible followed the described method by Turvey.² All patients had similar modified LeFort I downfracture osteotomies of Bennett and Wolford⁴ for the placement of interpositional bone grafts, performed through a circumvestibular mucosal incision from the distal aspect of the first molar to the contralateral side; for anterior, posterior, and inferior repositioning of the maxilla.

Following verification of the planned position of the maxilla, guided by a prefabricated occlusal splint and verified seating of the mandibular condyles in the glenoid fossae, the maxilla was initially secured with bilaterally placed Steinmann pins threaded into pretapped holes of each zygomatic eminence, and directed in a superolateral direction. These pins were subsequently engaged into the posterior wall of each zygomatic arch to enhance stabilization.^{4,36} These pins were bent at obtuse angles in the area of the maxillary first molar, and secured in the occlusal splint with self-curing acrylic. Following pin placement, two "L" shaped Luhr bone plates were passively positioned bilaterally around the piriform

aperture in close bone contact across the anterior osteotomy site, and secured with bone screws in pretapped holes.⁸ Careful consideration was given not to place torsional stresses on the maxillary segments during fixation.

All patients underwent bilateral sagittal split ramus osteotomies (SSRO) to either advance or setback the mandible. The SSRO procedure was originally described by Trauner and Obwegesser,^{37,38} and later modified by DalPont, Hunsuck, and Epker³⁹⁻⁴¹ for the advancement of deficient mandibles. The lateral cortical plate of bone of the proximal segment was reduced for setback procedures of prognathic mandibles. In all subjects, the mandible was rigidly fixed with bicortical self-tapping compression screw osteosynthesis (Jeter et al.¹²). The screw holes were tapped with an .062" threaded Steinmann pin and placed percutaneously. The proximal and distal segments were aligned with an intermaxillary splint, and removable lateral guide wire to check passive condylar seating similar to the technique described by Leonard,⁴² then secured with a cervical tenaculum to minimize condylar displacement during screw placement. The mandible was subsequently autorotated into its verified splint position to confirm passive condylar position, prior to intermaxillary fixation (IMF). The range for IMF stabilization was 2 to 7 days, contingent upon the amount of postoperative edema and soft tissue healing. The intermaxillary splints were 0.5mm to 2.5mm in thickness and not overcorrected. Following release of maxillomandibular fixation the splints were used with bilateral "training" elastics to posture the mandible upon closure for approximately 2 to 4 weeks.

Cephalometric Analysis

Each patient had standardized lateral cephalometric radiographs taken (Quint Sectograph, Los Angeles, CA.) preoperatively [T1], 2 to 6 days postoperatively [T2], and after an average long-term postoperative follow-up [T3] of 9 months, with a range of 6 to 16 months, (Fig. 1).^{15,24} Seven anatomic landmarks were identified on the T1 radiographs, (Fig. 2): nasion (N), sella (S), articulare (Ar), A point, B point, constructed gonion (CGo), and menton (Me). The points nasion and sella were transferred to each successive radiograph by superimposing on anterior and posterior cranial base structures. The landmarks articulare, A point, B point, menton, and constructed gonion were registered on successive

radiographs from T1 films using the "best-fit" method of superimposition. Each radiograph had a horizontal plane [HP] constructed seven degrees above the sella-nasion line registered at nasion (x-axis), and a vertical perpendicular plane registered at nasion (y-axis).⁴³

The coordinates of each landmark were recorded on a digitizer interfaced with an IBM-PC microcomputer. The coordinate values were obtained and analyzed using the Washington University orthodig program,⁴⁴ to determine defined angular and linear measurements, and measure magnitude changes in point position. All linear and point measurements were either perpendicular or parallel to the reference lines. Radiographic landmarks were digitized twice and point coordinates were averaged by the same investigator (J.H.L.) and reported to the nearest ± 0.1 mm or ± 0.1 degrees. To minimize the possible confounding effects of genioplasty procedures, changes in angular and linear measures were taken from B point. The method by which the (T2) cephalograms were available in this study maintained the intermaxillary surgical splints during the radiographic procedure. The (T2) radiographs were traced and the mandibles autorotated into intercuspatal position to assess the influence of splint thickness on changes in vertical dimension as it affected the total anterior facial height at B point. The vertical closure from splint removal ranged from 0.5 mm to 1.5 mm in the posterior occlusion, and 1.0 mm to 2.5 mm in the interincisal region.

Seven parameters (Figure 2) assessed skeletal stability. They were as follows: Three angular measurements [SN - CGo, ArCGo - CGoB pt., SN - CGoB pt.] defined mandibular proximal segment rotation, interfragment rotation between the proximal and distal segments, and distal segment rotation, respectively. Two linear measurements [S - CGo, CGo - B point] evaluated vertical displacements in posterior facial height, at constructed gonion, and horizontal displacements between constructed gonion and B point measuring changes in the effective mandibular length, parallel to the horizontal plane [H.P.]; thereby, evaluating interfragment interaction between the proximal and distal segments. Finally, changes along the vertical perpendicular plane [Y-axis] of A point to the horizontal plane measured the upper anterior facial height; likewise, vertical changes in B point measured the total

anterior facial height. Displacements in the horizontal direction (along H P) of these points assessed sagittal changes.

Table 1 summarizes the age, sex, diagnoses, length of postoperative follow-up (T2 to T3), and the surgical movements (in millimeters) performed for orthognathic correction (T1 to T2) along the (X) and (Y) axis for the maxilla (at A point), and the mandible (at B point) for each patient. Diagnoses were represented as follows: maxillary vertical excess [MVE], maxillary vertical deficiency [MVD], maxillary sagittal excess [MSE], maxillary sagittal deficiency [MSD], maxillary transverse deficiency [MTD], mandibular sagittal deficiency [MdSD], and mandibular sagittal excess [MdSE].⁷ Six patients had genioplasty procedures to advance or setback the chin. Two patients, represented in Table 1 as T.B and J.M., underwent unilateral left side and bilateral meniscopeplasties, respectively, to repair arthrographically confirmed internal disc derangements.

Statistical Method

Statistical analysis was performed by standard descriptive evaluation using Statview 512+ program.⁴⁵ The changes in each parameter from T1-T2, T2-T3, T1-T3, (Fig. 1) as well as the mean, range, and standard deviations were determined for these periods. The results were reported to the nearest ± 0.1 millimeters for linear measurements and ± 0.1 degrees for angular measurements (Table 2). Digitization error for the sample was calculated by digitizing each radiograph (T1, T2, and T3) twice in four consecutive patients. The standard deviations for each anatomic landmark parameter were averaged resulting in a linear measurement error of ± 0.4 mm, and angular measurement error of ± 0.6 degrees. These standard deviation error measurements can be attributed to nonbiologic variation, and are a function of error in landmark identification.

The emphasis of this study was to provide a descriptive profile of individual responses on the stability of skeletal segments following bimaxillary osteotomies using rigid internal fixation; moreover, to contrast our findings to the current literature on non-rigid and rigid stabilization.

RESULTS

The primary evaluation of stability in the maxilla and mandible were based on the horizontal and vertical displacements of A point and B point, in relation to the horizontal plane [H.P.] and the vertical perpendicular plane [Y-axis] registered at nasion. The data in Table 2 represent the actual linear and angular skeletal changes for each patient, following bimaxillary osteotomies from T1 to T2, and T2 to T3. The reported results are referenced from Table 2 unless otherwise specified.

Upper Anterior Facial Height Changes (H.P. - A point). The mean vertical decrease from T1 to T2 in upper anterior facial height following maxillary superior repositioning in eight patients was 4.3mm (3.3mm to 6.3mm) in a superior direction. The relapse in superior repositioning procedures were minimal in an inferior direction, with a mean of 0.4 ± 0.3 mm. Two patients underwent inferior repositioning procedures with bone grafts of 6.1mm and 7.1mm. The postoperative surgical changes in the superior direction was 0.8mm and 1.0mm, respectively. Vertical changes in upper anterior facial height were observed in seven patients with diagnosed transverse and sagittal dysplasias [MTD, MSE, and MSD], but no associated vertical problems. The mean surgical change from T1 to T2 was 0.4 ± 0.4 mm in a inferior direction, with stable fixation postoperatively (T2 to T3) in the range of ± 0.1 mm.

Maxillary Anteroposterior Changes (Y axis - A point). Six patients underwent surgical maxillary advancement for diagnosed sagittal deficiencies [MSD] with a mean surgical advancement of 3.6 mm (2.0mm to 4.8 mm). Relapse occurred with a mean of 0.4 ± 0.2 mm in a posterior direction. Five patients underwent maxillary surgical setback procedures for sagittal excess [MSE] with a mean decrease of 4.6 mm (3.9 mm to 5.8 mm). Relapse of 0.5 ± 0.4 mm in a forward direction occurred. The remaining five patients in the sample demonstrated small horizontal changes for the correction of primarily maxillary transverse and/or vertical dysplasias [MVE, MVD, and MTD]. The surgical changes (T1 to T2) ranged from 0.8mm setback to 1.3mm advancement of A point, with stable postoperative changes (T2 to T3) of ± 0.3 mm.

Mandibular Anteroposterior Changes (Y axis - B point). Thirteen patients underwent bilateral sagittal split ramus osteotomies to advance the mandible with a mean increase of 6.1 mm (3.6 mm to 10.4 mm) at B point. Nine (69%) of the mandibular advancement cases demonstrated forward displacement of B point at the T2 to T3 interval, thereby, increasing the effective mandibular length. This forward movement of the mandible from T2 to T3 averaged 0.8 mm (0.5mm to 1.2mm), which also resulted in small increases in the effective mandibular length (mean of 0.5mm). Four of these nine mandibular advancements (31%) demonstrated relapse with a mean loss of 1.0 ± 0.3 mm; however, these changes occurred in those patients with the largest mandibular advancements, (8.4mm to 10.4mm). There was also an associated decrease in effective mandibular length (T2 to T3) with a mean of 0.8 ± 0.1 mm. Three patients underwent BSSRO procedures to setback the mandible with a mean setback of 4.5 ± 0.6 mm. These three patients demonstrated a relapse tendency with a mean forward displacement in B point of 0.7 ± 0.2 mm, and an increase in effective mandibular length with a mean of 0.6 ± 0.1 mm. Changes in effective mandibular length (CGo - B point) closely paralleled the anteroposterior changes in B point in all patients (Table 2).

Total Anterior Facial Height Changes (H.P. - B point). The vertical displacement of B point measured changes in the total anterior facial height (AFH). Eight patients following maxillary impactions for VME and mandibular advancement procedures, showed decreases in total AFH (T1 to T2) with a mean of 2.5 ± 0.7 mm due to maxillary superior repositioning at A point. The postoperative change (T2 to T3) resulted in an additional decrease in AFH of mean 1.3 ± 0.2 mm, primarily attributed to mandibular autorotation following splint removal. Six patients who underwent primarily sagittal and transverse maxillary correction demonstrated increases in AFH of mean 2.5 ± 0.7 mm; however, following intermaxillary splint removal there was an additional increase of mean 0.6 ± 0.1 mm. Significant increases in AFH, 7.4mm and 8.1mm, occurred in two patients (P.C. and S.G.) that underwent correction for maxillary vertical deficiency [MVD]. The net increase (T1 to T3) in AFH following splint removal was 5.1mm and 6.4mm, respectively. Mandibular autorotation following IMF accounted for 85% to 95% of the vertical displacement at B point. The net long-term vertical changes (T1 to T3) in total AFH

showed eight patients demonstrating decreases in facial height, ranging from 2.8mm to 5.6mm. Eight patients had overall increases in facial height ranging from 0.4mm to 6.4mm.

Posterior Facial Height Changes (S - CGo). The mean decrease in posterior facial height for the group with VME was $1.7 \pm 0.3\text{mm}$, and the mean decrease in PFH for the group without VME was $0.7 \pm 0.2\text{mm}$. The individual variation in relapse was minimal with a mean of $0.3 \pm 0.1\text{mm}$. Two patients (P. C. and S. G.) showed increases in posterior facial height of 3.6mm and 3.7mm, respectively. These inferior movements of the proximal segment resulted in subsequent post-surgical changes (T2 to T3) of 1.4mm and 1.6mm in a superior direction. Mandibular autorotation in an anterosuperior direction following splint removal accounted for the majority of the T2 to T3 postoperative changes.

Changes In Angular Measures: Proximal Segment Rotation (SN - ArCGo), Ramus-Body Angle (ArCGo - CGoB pt.), and Mandibular Plane Angle (SN - CGo B pt.).

Eleven patients demonstrated a tendency for anterosuperior (counterclockwise) rotation of the proximal segment following surgical advancement of the mandible, resulting in a more obtuse (clockwise) ramus-body angle, and mandibular plane angle. The magnitude of anterosuperior rotation of the proximal segment resulted in concurrent changes in magnitude of the ramus-body and mandibular plane angles; moreover, changes in the mandibular plane angle coincided closely with changes in the ramus-body angle. The two patients with maxillary vertical deficiency (P.C. and S.G.) following mandibular advancements and maxillary inferior repositioning, demonstrated an opposite (clockwise) rotation of the proximal segment, and counterclockwise rotation of the ramus-body angle, and the mandibular plane angle. The three patients that underwent mandibular setbacks demonstrated counterclockwise rotation of the proximal segment; however, unlike the mandibular advancement the ramus-body and mandibular plane angles became more acute from T1 to T2, demonstrating counterclockwise rotation.

Following mandibular advancements the mean changes (T1 to T2) for the eleven patients demonstrating counterclockwise rotation of the proximal segment (SN - ArCGo) was 2.4 ± 0.6 degrees, the intersegment changes between the proximal and distal segments (ramus-body angle, ArCGo - CGo

B pt.) was 4.4 ± 0.7 degrees of clockwise rotation, and the mandibular plane angle was 3.8 ± 0.7 degrees in a clockwise direction. The relapse demonstrated minimal angular changes in a counterclockwise, and limited individual variability with regard to the surgical changes reported. The mean changes from T2 to T3 for the proximal segment showed slight rotation in a counterclockwise direction of 0.6 ± 0.2 degrees. The intersegment changes rotated in a counterclockwise direction with a mean of 1.0 ± 0.2 degrees. The mandibular plane angle likewise rotated in a counterclockwise direction with a mean of 1.0 ± 0.3 degrees.

The two cases which underwent correction of MVD with mandibular advancement showed clockwise rotation of the proximal segment (T1 to T2) with a mean of 4.5 ± 0.2 degrees, the intersegment changes of the ramal-body angle in a counterclockwise direction was 5.3 ± 0.2 degrees, and the mandibular plane angle rotated on the average of 4.5 ± 0.2 degrees in a counterclockwise direction. The relapse in these two cases demonstrated the most variability, ranging from 48% to 68%. The mean changes from T2 to T3 in the proximal segment were 2.5 ± 0.2 degrees, intersegment changes were 3.4 ± 0.1 degrees, and mandibular plane angle 2.4 ± 0.1 degrees of clockwise rotation.

The three patients that underwent mandibular setbacks (T1 to T2) showed a mean proximal segment counterclockwise rotation of 1.6 ± 0.2 degrees, with concurrent closure of the ramal-body angle, mean 4.0 ± 0.6 degrees, and the mandibular plane angle with a mean of 3.6 ± 0.7 degrees. The magnitude of postoperative change was relatively minimal with respect to the surgical changes (T1 to T2); however, the direction of relapse resulted in slightly more acute (counterclockwise) angular changes of SN-ArCGo, ArCGo-CGoB pt., and SN-CGoB pt. consistent with mandibular autorotation following splint removal. The proximal segment rotated in a counterclockwise direction by a mean of 0.5 ± 0.2 degrees, the ramal-body angle decreased 1.0 ± 0.2 degrees, and the mandibular plane angle decreased 0.9 ± 0.1 degrees in a counterclockwise direction.

Discussion

Because of the extended length of maxillomandibular fixation, relapse following combined double-jaw procedures using non-rigid fixation are not independent in the maxilla and mandible.^{1,2,21,22,31} In contrast, because of the shorter periods of intermaxillary fixation, transoral rigid skeletal stabilization in combined two-jaw surgery may respond as two independent procedures with regard to the stability of dentosseous segments.^{5-10,13,14}

Several studies have reported excellent surgical stability in bimaxillary mobilizations, discussed modifications in surgical techniques to prevent type I/II relapse as described by LeBanc et al.,¹ and have evaluated the mechanisms responsible for skeletal relapse; nevertheless, very few studies in the reported literature have quantitated the results of bimaxillary osteotomies which permit comparative assessments between non-rigid and rigid fixation systems.^{1-10,20,31,32,36} Brammer, Finn, Bell et al.,³¹ report on stability after bimaxillary surgery to correct vertical maxillary excess and mandibular deficiency using non-rigid fixation, provided the majority of comparative data with long-term follow-up.

The relationships of surgical movements in the maxilla (T1 to T2) with the postsurgical relapse (T2 to T3) demonstrated very stable fixation of the maxilla in all directions for superiorly, inferiorly, and sagittally repositioned segments. Individual variation was observed although small in magnitude and direction. Vertical relapse at A point in a inferior direction for superior repositioning procedures was a function of the amount of surgical intrusion; that is, the greater the intrusion the more postoperative relapse in a downward direction. Brammer et al.,³¹ in a study of 12 subjects with VME and high-angle mandibular deficiency reported similar relapse of A point, $0.4 \pm 2.0\text{mm}$ in an inferior direction. However, our study demonstrated six times less variation in magnitude, mean $0.4 \pm 0.3\text{mm}$. Comparable maxillary advancements were also performed in this study as previously reported; however, the magnitude of relapse in a posterior direction was not closely related to the surgical advancement. These findings were also consistent with Brammer et al.³¹ The mean surgical advancement of the maxilla was $3.6 \pm 0.8\text{mm}$ with rigid fixation in this study, in contrast to $3.3 \pm 2.0\text{mm}$ using non-rigid fixation. Posterior

relapse using rigid fixation in maxillary sagittal advancements was $0.4 \pm 0.2\text{mm}$ in this study, as opposed to $1.0 \pm 1.6\text{mm}$ using non-rigid stabilization.³¹ The use of rigid fixation in stabilizing maxillary segments for superior repositioning procedures provides excellent stability; however, the major advantages of rigid vs. non-rigid systems become more obvious when requirements for greater stabilization in maxillary osteotomies are needed due to compromised bony approximations, and complete immobilization of bone grafts are paramount for osseous healing.^{3,31}

Vertical changes from T2 to T3 in inferior repositioning, with interpositional grafts (patients P.C. and S.G.), were observed to be stable with postoperative relapse of less than 14% in an upward direction. Although the method of rigid internal fixation in the maxilla (using bilateral bone plates at the lateral inferior aspect of the piriform aperture, and bilaterally placed Steinmann pins in the zygomatic buttress, a method used by K.S.R. to reduce operating time and improve surgical efficiency⁴⁶) was a modification of that reported by other investigators, the findings were consistent with the observations that have reported maxillary stability after LeFort I osteotomies using only bone plates for rigid stabilization.^{4,6-9,36}

Stability studies in the reported literature for maxillary inferior repositioning procedures have lacked quantitative descriptions; however, earlier studies have reported far less stable results in inferior repositioning procedures using transosseous wire fixation with bone grafts.⁴⁷⁻⁴⁹ Although the precise mechanisms of this relapse have been difficult to ascertain, it has been suggested that use of suspension wires requires more precise graft placement than rigid fixation, as the mobilized segments may rotate around the wires; in addition, compromised intraoperative bony approximations leads to difficult stabilization.³³ These etiologic factors have warranted the use of more rigid fixation techniques. Bone plates, and stabilization pins are believed to provide better long-term stability because of enhanced segment immobilization with interpositional bone grafts; thereby, providing a more stable osseous matrix for bone maturation and remodeling.⁴⁹

Maxillary setbacks have been considered stable procedures using suspension wires, and interosseous wire fixation to stabilize skeletal segments.⁴⁷ Stability data for maxillary sagittal excess and

transverse deformities have been for the most part empirical observations, and discussions of surgical technique. Our results demonstrated favorable stability and minimal relapse in the range of 0.4mm to 0.8mm in a forward direction following maxillary setbacks. These changes did not reflect bony relapse, but more likely error in landmark identification, and possible postsurgical orthodontic compensations. Carlotti⁴⁸ found that postoperative orthodontic changes due to inadequate presurgical dental decompensations accounted for 75% of the postoperative relapse, in rigidly immobilized LeFort I osteotomies. Similar findings were observed for the five cases primarily treated for maxillary transverse dysplasias; in that, minimal postoperative changes were observed.

In a recent paper Singer and Bays²⁶ compared superior border wires with inferior border wires in mandibular advancements; however, the data of ten bimaxillary osteotomies were pooled with the mandibular surgeries. With superior border wires in the bimaxillary cases, they found an average counterclockwise rotation of the proximal segment of 7.7 degrees, clockwise rotation of the distal segment of 7.8 degrees, and clockwise intersegment rotation of 6.3 degrees. When inferior border wires were used the average counterclockwise rotation of all three angles were 3.5, 3.2, and 0.4 degrees, respectively. Lake et al.,²⁴ study of 51 subjects who underwent sagittal split ramus osteotomies using superior border wire fixation, reported counterclockwise rotation of the proximal segment, and clockwise rotation of the distal segment. Will et al.,²⁸ group of 41 patients reported the same rotational movements in the mandibular segments. They found significant increases in gonial and mandibular plane angles, and decreases in gonial arc radius. Our data compared similarly in magnitude with the ability of lower border wires to maintain the position of the proximal segment; moreover, the directional changes of the proximal and distal segment were in agreement with those reported by Lake et al., and Will et al.^{24,26,28} Van Sickels et al.,¹³ evaluated relapse using rigid fixation in mandibular advancements without genial procedures reporting an average (T2 to T3) counterclockwise rotation of the proximal segment of 0.5 ± 2.6 degrees, clockwise distal segment rotation of 1.3 ± 4.1 degrees, and clockwise intersegment rotation of 0.0 ± 3.2 degrees. This compared favorably with the results obtained in this study.

The inability to control the proximal segment, and functionally seat the condyle in the glenoid fossa when fixation has been applied, has also been cited as a primary factor resulting in relapse during maxillomandibular fixation or following release of fixation.¹⁹⁻²⁴ Schendel and Epker²¹ using non-rigid fixation reported 45% relapse in their cases determined to be attributed to condylar distraction at the time of surgery. The use of rigid fixation as described in this study and by other investigators permitted checking the functional position of the condyles after screw placement for internal fixation.^{12,13} Controversy over methods to prevent condylar displacement or "sag" has received blame on the technical shortcomings of the surgeon.⁵¹ However, in recent years Leonard⁵² has devised methods to accurately reseat the condyles and position the proximal segment following SSRO procedures. Condylar seating in our study was verified in a comparable manner; moreover, passive autorotation into the surgical splint, and laminographic follow-up accounted for stable condylar repositioning, and minimal postoperative mandibular changes.⁴²

With removal of the intermaxillary splint there was an average of 1.4mm of mandibular closure in a counterclockwise direction with no significant change (0.3 degrees) between the proximal and distal segments (ArCGo-CGoB pt.), and a small counterclockwise rotation of the distal segment (SN-CGoB pt.), 0.6 degrees. These changes are consistent with splint removal and postoperative orthodontic settling. Similar findings have been reported by Van Sickels et al.¹³ following mandibular advancements using rigid internal fixation. However, osseous remodeling of the gonial region due to periosteal reattachment, revascularization, and muscle reattachment of the pterygomasseteric sling following sagittal split ramus osteotomy procedures may have been etiologic factors. Henrickson et al.,⁵³ group of thirty-five adult rhesus monkeys experimentally induced significant gonial remodeling by surgically stripping the pterygomasseteric sling, and associated blood supply in conjunction with increases in vertical dimension. Rigid stabilization with good bony apposition of the mandibular segments during fixation, conservative tissue reflection, efforts to accurately position the condyles in the fossae while maintaining the preoperative orientation of the pterygomasseteric sling, and reduced tension of the

paramandibular tissues and muscles have been ascribed by various authors as essential factors for optimal maintenance of postsurgical skeletal stability in SSRO procedures.^{13,14,21,22,24,27,28,51}

The effect of increases in posterior facial height (PFH) on the type, direction, and magnitude of maxillary osteotomies and mandibular osteotomy procedures were significant. The direction and magnitude of proximal segment rotation directly related to the effects on posterior facial height. That is, in maxillary superior repositioning, sagittal and transverse corrective procedures (14 cases) decreases in posterior facial height occurred (T1 to T2) with a mean of $1.3 \pm 0.6\text{mm}$ in a superior direction, and postoperative changes (T2 to T3) of $0.3 \pm 0.1\text{mm}$ in a superior direction. Brammer et al.,³¹ reported increased posterior facial height changes (T1 to T2) of mean $3.6 \pm 3.2\text{mm}$, and decreases in PFH postoperatively (T2 to T3), with a mean relapse of $3.9 \pm 3.2\text{mm}$. Since posterior facial height (S - CGo) measurements reflect possible changes in the posterior maxilla and/or proximal segment, these results reflected good control of the proximal segment and immobilization of maxillary segments with rigid fixation. Quantitative comparisons of our results to other bimaxillary studies were limited. Harsha and Terry⁷ study on five bimaxillary cases using maxillary bone plates reported good bony stabilization. Van Sickels et al.,¹⁴ evaluated four cases of mandibular and genial advancements with rigid fixation, and noted decreases in PFH (T1 to T2) of $0.1 \pm 1.9\text{mm}$ and relapse (T2 to T3) of $1.1 \pm 2.4\text{mm}$. Two cases of maxillary vertical deficiencies [MVD] demonstrated 43% relapse in PFH; however, these changes were small in magnitude. Clockwise rotation of the proximal segment demonstrated relapse in the range of 48% to 63%. The ramal-body angle and mandibular plane angles showed similar relapse of 53% to 67% in a clockwise direction. Although the mechanism by which this relapse occurred is difficult to ascertain, the leading factors include possible intraosseous mobility, condylar and gonial remodeling, and bone graft remodeling.^{1,48,49,53}

Thomas et al.¹⁵ examined early skeletal changes in a 6 week follow-up study comparing wire osteosynthesis to rigid screw fixation in the treatment of mandibular sagittal deficiencies. Thirty-four patients had SSRO mandibular advancements. The rigid group had 3 to 7 days of IMF while the wire group maintained 6 week of intermaxillary fixation. Significant differences in relapse were reported in

the horizontal and vertical direction of B point. The rigid group demonstrated a 10% forward displacement at B point (T2 to T3) with a mean of $0.5 \pm 2.1\text{mm}$. Likewise, this study showed a slight net gain of $0.3 \pm 0.9\text{mm}$ following mandibular advancements and forward positioning due to autorotation. The wire group showed 24% relapse (T2 to T3) with a mean of $1.1 \pm 1.4\text{mm}$ in a posterior direction. The vertical changes in the rigid group demonstrated a slight decrease in anterior facial height by an average of $0.2 \pm 1.7\text{mm}$ at B point; while the wire group showed an increase in AFH with a mean of $1.4 \pm 1.6\text{mm}$. Our data supported these findings with vertical facial height decreases using rigid fixation, following IMF splint removal and mandibular autorotation. Numerous etiologies have been reported to account for relapse in mandibular advancements due to the effects of posterior elastic forces from investing soft tissues; however, little is understood between the interaction of preventing condylar remodeling and surgical stability. Rigid internal fixation has been widely advocated to provide adjunctive skeletal stabilization; however, current applications of rigid fixation may enhance the transmission of posterior forces to the condyles from stretched paramandibular tissues; thereby, causing condylar remodeling and delayed relapse as described by LeBanc et al.¹ They reported this condition following bimaxillary surgeries with non-rigid fixation, in which several cases exhibited good short-term stability; however, following a 6 to 24 month duration a slow measurable relapse occurred "...secondary to condylar resorption or negative remodeling."

Factors causing the decreases in effective mandibular length observed in this study were not clearly identified. Several reports have suggested intersegment plasticity using non-rigid wire fixation;^{24,28} however, this observation does not seem plausible using the methods described for rigid stabilization in this study. Henrickson et al.,⁵³ has suggested that significant gonial remodeling may occur as a result of vascular compromise or necrosis, and stretching of the pterygomasseteric sling beyond physiologic boundaries. Although these cases did not violate accepted surgical techniques, gonial remodeling may have been a factor, reflected by the observed decreases in effective mandibular length, following the larger magnitudes of mandibular advancements.

The three cases that underwent mandibular setbacks, demonstrated 14% relapse of $0.6 \pm 0.2\text{mm}$ in a forward direction. These findings were consistent with counterclockwise mandibular autorotation with splint removal, and slight decreases in posterior facial height which resulted in stable fixation. Paulus and Steinhauser¹⁸ comparative study between wire osteosynthesis and rigid screw fixation in 146 subjects treated for mandibular prognathism, observed sagittal relapse in 7% and vertical relapse in 5% of the cases with rigid fixation, compared to 17.5% sagittal relapse and 15% vertical relapse with wire osteosynthesis.

The effects of mandibular surgery on maxillary stability using rigid internal fixation were not as described by Epker and Wessberg²² following bimaxillary osteotomies using non-rigid fixation; however, the skeletal segments interacted independent of one another primarily as a result of the limited period for maxillomandibular fixation. Relapse was a factor in both jaws primarily dependent on the magnitude of surgical repositioning in either jaw; however, these postoperative changes (T2 to T3) were minimal when compared to non-rigid fixation. Reports have indicated that maxillary rigid stabilization is adequate anchorage for the use of non-rigid wire fixation in mandibular procedures with IMF stabilization.³¹ Other studies have stated that bone screw osteosynthesis in sagittal split ramus osteotomies minimizes the need for IMF without significant effects on skeletal stability; thereby, allowing patients to maintain better oral hygiene, and resuming masticatory function sooner and more efficiently.¹¹⁻¹³

In summary, stability following combined double-jaw procedures was excellent with minimal tendency for relapse. Maxillary and mandibular stability was primarily a function of the surgical changes in magnitude (T1 to T2), with demonstrated relapse exhibiting independent behavior within the maxillary and mandibular osteotomy.

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Figure Legend

Fig. 1 Time intervals for cephalometric assessment: the surgical and early post-operative changes, T1-T2; net post-surgical changes, T2-T3; net long-term surgical changes, T1-T3.

Fig. 2 Anatomic landmarks used to evaluate angular and linear parameters to assess skeletal stability. 1, Nasion (N). 2, Sella (S). 3, Articulare (Ar). 4, Constructed Gonion (CGo). 5, A point. 6, B point. 7, Menton (Me). A, Mandibular plane angle (SN - CGoB pt.). B, Ramus angle (SN - ArCGo). C, Ramus-Body angle (ArCGo - CGoB pt.). D, Posterior facial height (S - CGo). E, Effective mandibular body length (CGo - B pt.). F, Upper anterior facial height (H.P. - A point). G, Total anterior facial height (H.P. - B point).

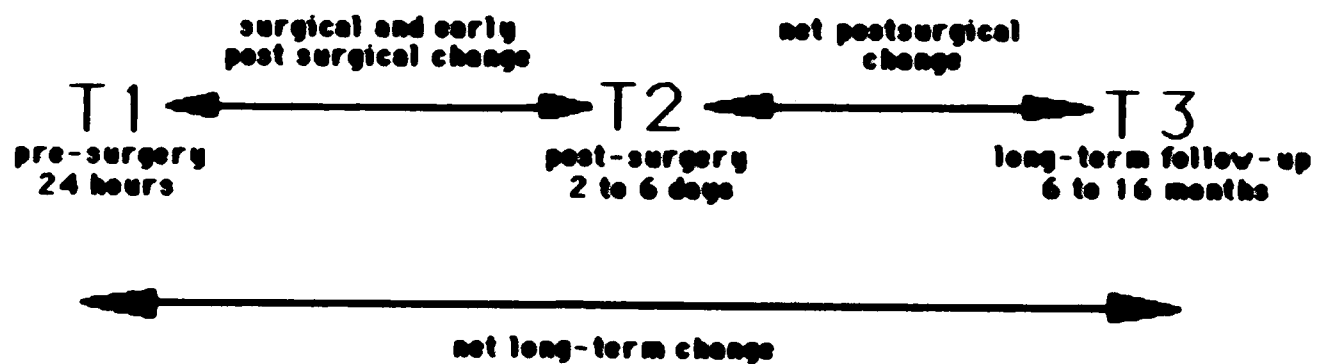


Figure 1

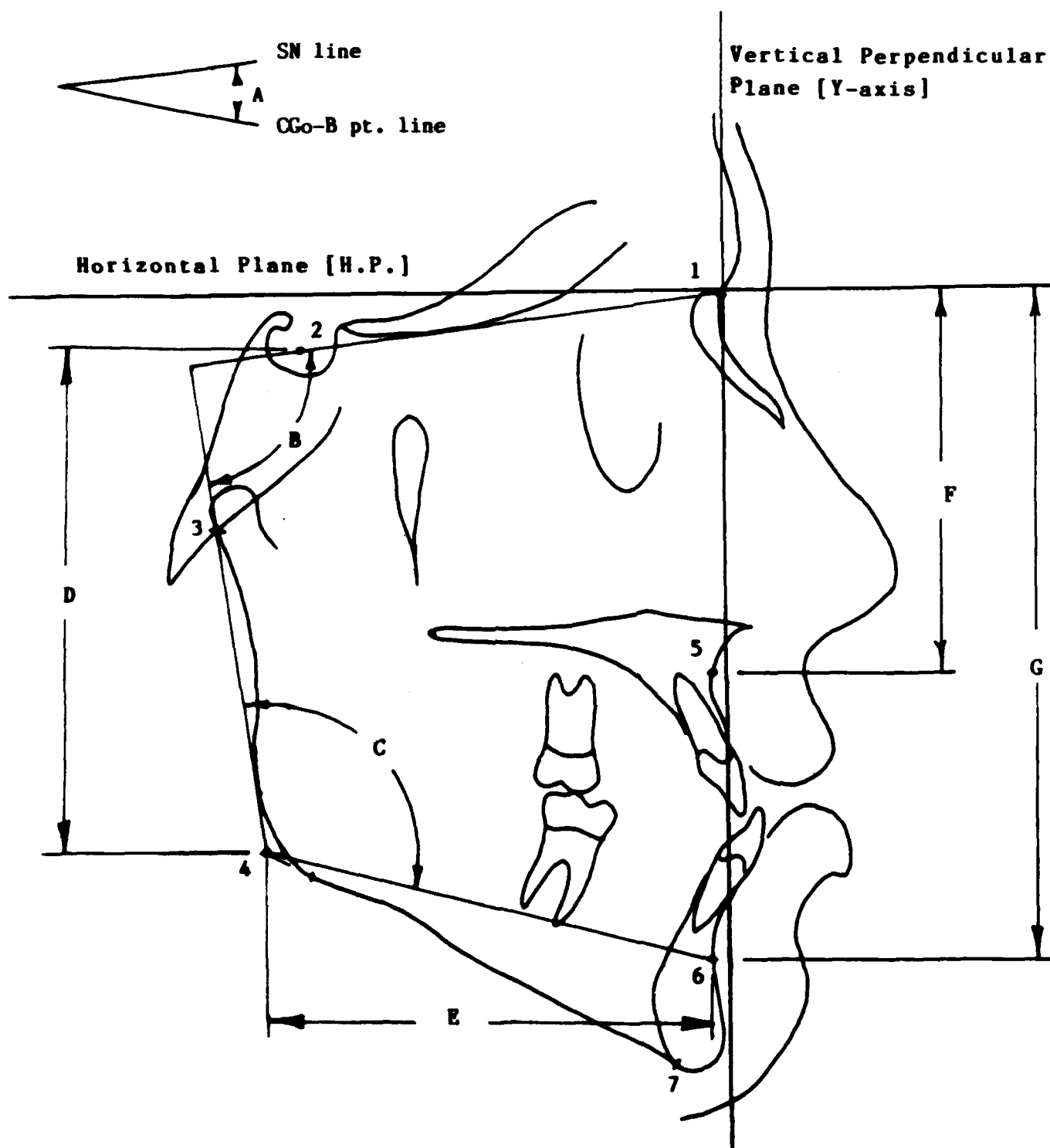


Figure 2

Table 1. Patient profile and surgical changes, T1-T2.

Patient	Age	Sex	Diagnosis	Long-Term	Treatment			
				Follow-up(mos.)	Maxilla (mm)		Mandible (mm)	
				(T2 to T3)	[X]	[Y]	[X]	[Y]
1. B.B.	31 ⁸	F	MYE, MSD, MdSD	6	+3.3	+3.3	+8.4	+2.1
2. H.Fr.	43 ⁵	F	MYE, MdSD	8	-0.3	+3.8	+5.6	+2.8
3. S.H.	37 ³	F	MYE, MSE, MdSD	6	-3.9	+3.5	+5.1	+2.4
4. Y.H.	32 ¹	F	MYE, MSD, MdSD	8	+2.0	+6.3	+8.4	+4.0
5. J.M.	22 ⁵	F	MYE, MSE, MdSD	16	-5.8	+4.3	+4.4	+1.5
6. D.P.	34 ¹¹	F	MYE, MSE, MdSD	7	-4.2	+3.5	+4.1	+2.3
7. D.R.	31 ⁸	F	MYE, MSD, MTD, MdSD	7	+3.8	+5.6	+10.4	+2.8
8. B.R.	25 ⁰	F	MYE, MTD, MdSD	6	+1.3	+4.5	+10.2	+2.4
9. P.C.	33 ⁸	F	MYD, MdSD	14	+1.1	-6.1	+3.6	-7.4
10. S.G.	30 ⁶	M	MYD, MSD, MdSD	9	+4.8	-7.1	+4.1	-8.1
11. H.F.	32 ¹⁰	F	MTD, MdSD	13	-0.8	-0.3	+6.1	-2.3
12. D.H.	34 ²	M	MSE, MTD, MdSD	11	-5.3	-0.5	+4.8	-3.4
13. D.S.	21 ⁶	M	MSE, MTD, MdSD	10	-4.0	-0.7	+4.1	-2.5
14. T.B.	20 ¹	M	MTD, MdSE	8	+0.5	-0.3	-5.3	-2.9
15. S.H.	14 ¹⁰	F	MSD, MTD, MdSE	6	+3.7	-0.3	-4.0	-1.6
16. L.W.	21 ⁵	F	MSD, MTD, MdSE	7	+3.9	-0.3	-4.3	-2.1

1. The ages of the patients are indicated in years and months. The treatment values represent changes (T1 to T2) in millimeters. Patients T.B. and J.M. also underwent left side and bilateral menisoplasties, respectively, concurrently with orthognathic surgery. The diagnoses represent the following: [MYE] maxillary vertical excess, [MYD] maxillary vertical deficiency, [MSE] maxillary sagittal excess, [MSD] maxillary sagittal deficiency, [MTD] maxillary transverse deficiency, [MdSD] mandibular sagittal deficiency, and [MdSE] mandibular sagittal excess.

2. Positive (+) values indicate anterior/superior movement relative to the previous position; Negative (-) values indicate posterior/inferior movement relative to the preceding position.

Table 2. Skeletal Changes (T1-T2) and Release (T2-T3) following bimaxillary osteomies, linear and angular measurements

Patient	A point Changes ¹			B point Changes ¹			Effective Mandibular Length ¹		Posterior Facial Height ¹		Ramus Angle ²		Remal-Body Angle ²		Mandibular Plane Angle ²	
	Sagittal Change (X)	Upper Anterior Facial Height (Y)	Total Anterior Facial Height (Y)	Sagittal Change (X)	T1-T2	T2-T3	CCo - B point	T1-T2	T2-T3	S - CCo	T1-T2	T2-T3	ArCCo - CCoB pt.	T1-T2	T2-T3	SN - CCoB pt.
Correction for: Maxillary Vertical Excess [with / without transverse and/or sagittal correction]																
B B	+3.3	-0.4	+3.3	-0.1	+8.4	-0.8	+2.1	+1.3	+8.0	-0.7	+1.3	+0.4	-2.2	-0.9	+3.6	-0.8
H Fr	-0.3	-0.1	+3.8	-0.2	+5.6	+0.5	+2.8	+1.2	+4.8	+0.6	+1.4	+0.6	-2.5	-0.8	+3.6	-1.3
S H	-3.9	+0.5	+3.5	-0.2	+5.1	+0.8	+2.4	+1.1	+4.9	+0.6	+1.5	+0.4	-2.7	-0.9	+4.8	-1.2
V H	+2.0	-0.2	+6.3	-0.8	+8.4	-0.8	+4.0	+1.6	+8.0	-0.6	+2.3	+0.3	-3.1	-0.9	+5.2	-0.8
J M	-5.8	+0.6	+4.3	-0.6	+4.4	+0.7	+1.5	+1.3	+3.8	+0.5	+1.8	+0.4	-2.7	-0.6	+4.9	-1.2
D P	-4.2	+0.4	+3.5	-0.2	+4.1	+0.5	+2.3	+1.1	+3.8	+0.5	+1.3	+0.4	-2.6	-0.4	+4.3	-1.1
D R	+3.8	-0.8	+5.6	-1.0	+10.4	-1.3	+2.8	+1.6	+10.0	-0.9	+2.1	+0.5	-3.2	-0.6	+5.1	-1.5
B R	+1.3	+0.1	+4.5	-0.6	+10.2	-1.3	+2.4	+1.3	+9.8	-0.9	+1.6	+0.3	-2.8	-0.6	+3.9	-1.3
Correction for: Maxillary Vertical Deficiency [with / without sagittal correction]																
P C	+1.1	-0.3	-6.1	+1.0	+3.6	+1.0	-7.4	+2.3	+3.3	+0.4	-3.6	+1.4	+4.4	-2.1	-5.1	+3.2
S G	+4.8	+0.5	-7.1	+0.8	+4.1	+1.2	-8.1	+1.6	+3.8	+0.5	-3.7	+1.6	+4.7	-2.9	-5.5	+3.6
Correction for: Maxillary Transverse Deficiency [with / without sagittal correction]																
1. Mandibular Advancements																
H F	-0.8	+0.2	-0.3	+0.1	+6.1	+0.9	-2.3	+2.0	+5.9	+0.6	+0.8	+0.2	-1.4	-0.4	+3.3	-0.6
D H	-5.3	+0.8	-0.5	+0.1	+4.8	+1.1	-3.4	+2.9	+4.1	+0.6	+0.6	+0.1	-1.4	-0.5	+3.7	-0.7
D S	-4.0	+0.4	-0.7	-0.1	+4.1	+0.9	-2.5	+1.6	+3.8	+0.5	+0.9	+0.4	-1.7	-0.6	+3.6	-1.1
2. Mandibular Setbacks																
T B	+0.5	+0.3	-0.3	0.0	-5.3	+1.0	-2.9	+1.6	-4.9	+0.8	+0.9	+0.4	-1.7	-0.7	-4.9	-1.2
S H	+3.7	-0.6	-0.3	0.0	-4.0	+0.4	-1.7	+1.2	-3.5	+0.6	+0.5	+0.1	-1.7	-0.3	-3.9	-0.7
L V	+3.9	-0.2	-0.3	0.0	-4.3	+0.6	-2.1	+1.7	-4.0	+0.7	+0.5	+0.2	-1.5	-0.4	-3.4	-1.1

¹ Treatment values are in millimeters. Positive (+) linear changes indicate anterior/superior movement relative to the previous position, negative (-) linear changes indicate posterior/inferior movement relative to the previous position.

² Treatment values are in degrees. Positive (+) angular changes indicate clockwise relation relative to the previous position, negative (-) angular changes indicate counter-clockwise relation relative to the previous position.

END

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